Recent Mascon Solutions from GRACE

D.N. Yuan and M.M. Watkins

Jet Propulsion Laboratory

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JPL CSR GFZ POTSDAM

Overview

- GRACE gravity validation solutions
- Harmonic solution
- Mascon (mass concentration) solution
- Comparisons of harmonic and mascon solutions
- Summary
- Future works

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JPL GRACE Gravity Validation Solution

- KBR1B, GPS1B, ACC1B, SCA1B, and AOD1B from GRACE Level-1 products.
- Validation GRACE solutions Jan 2003 - Dec 2005 :
  - Release 2 harmonic solutions using AOD RL01 and RL03 (PPHA and OMCT based ocean models)
  - JPL release 2 parameterization proven effective, harmonic solutions are demonstrated state-of-the-art
- Mascon solution using AOD RL01 (PPHA-based)
  - Several variants (area dimension, correlation, etc)

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Background Model Improvement

- Nominal gravity model - GGM02C to degree 180
- IERS 2003
  - J2-dot, C21/S21-dot
  - solid earth tide
  - solid earth pole tide
- Ocean tide using convolution formalism with weights derived from FES04 model to degree 60 (Desai)
- Ocean pole tide SCEQ (Desai) model to 30x30

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Harmonic Solution

- FLINN GPS ephemeris and clock solution

- Parameterization for GRACE orbit determination
  - Daily ACC biases
  - KBR empirical biases every orbital revolution
  - Stochastic GPS transmitter clock & GPS-GRACE phase biases

- Estimated gravity harmonics
  - 120x120 harmonic partials from KBRR data
  - 90x90 harmonic partials from GPS data.

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JPL Mascon Implementation

- Mascon models in MIRAGE software
  - – Point mass, flat disk, **spherical cap** and spherical ring
  - – Equal area or variable area (with latitude)
  - – Compute direct gravity acceleration from mascons, no truncation from any conversion to harmonics
- Same dynamic models, parameterization, and reference orbit for GRACE as our harmonic solution.
- Simultaneous solution for all mascon regions
  - – Use both GPS and KBRR data for solution

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Advantages of Mascon Basis vs. Spherical Harmonic Basis Functions

- The mass concentration solution is localized in both time and space.
  - Weakens correlations between regional solutions
    - Less “leakage” and propagation of long period errors
  - The application of spatial constraints are easier to implement than with spherical harmonics
  - Potentially higher temporal and spatial resolution than harmonic solution
    - Make use of actual groundtracks over each mascon rather than limited by equatorial ground track spacing

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Mascon Solution

- Estimated globally distributed 4°x4° equal-area spherical cap mascons

- Optionally apply a spatial correlation of the form:

$$e^{-(d_{ij}/D)}$$

d_{ij} is the angular distance between mascon *i* and *j*;

D is the correlation distance

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Post-processing of Harmonic and Mascon Solutions in Surface Water Variations

- Gaussian spectral smoothing with a spherical cap applied to harmonic solutions (Swenson and Wahr, 2002).

$$\Delta \mathbf{H}_{\mathbf{water}}(\phi,\lambda) = \frac{2\pi \mathbf{a_e}}{3} \frac{\bar{\rho}_{\mathbf{earth}}}{\rho_{\mathbf{water}}} \sum_{\ell=0}^{\infty} \sum_{\mathbf{m}=0}^{\ell} \frac{2\ell+1}{1+\mathbf{K}_\ell} \mathbf{W}_\ell \bar{P}_{\ell\mathbf{m}}(\sin\phi) \cdot \left[\Delta\bar{\mathbf{C}}_{\ell\mathbf{m}} \cos \mathbf{m}\lambda + \Delta\bar{\mathbf{S}}_{\ell\mathbf{m}} \sin \mathbf{m}\lambda\right]$$

- Gaussian discrete smoothing with a spherical cap applied to mascon solutions (Jekeli, 1981).

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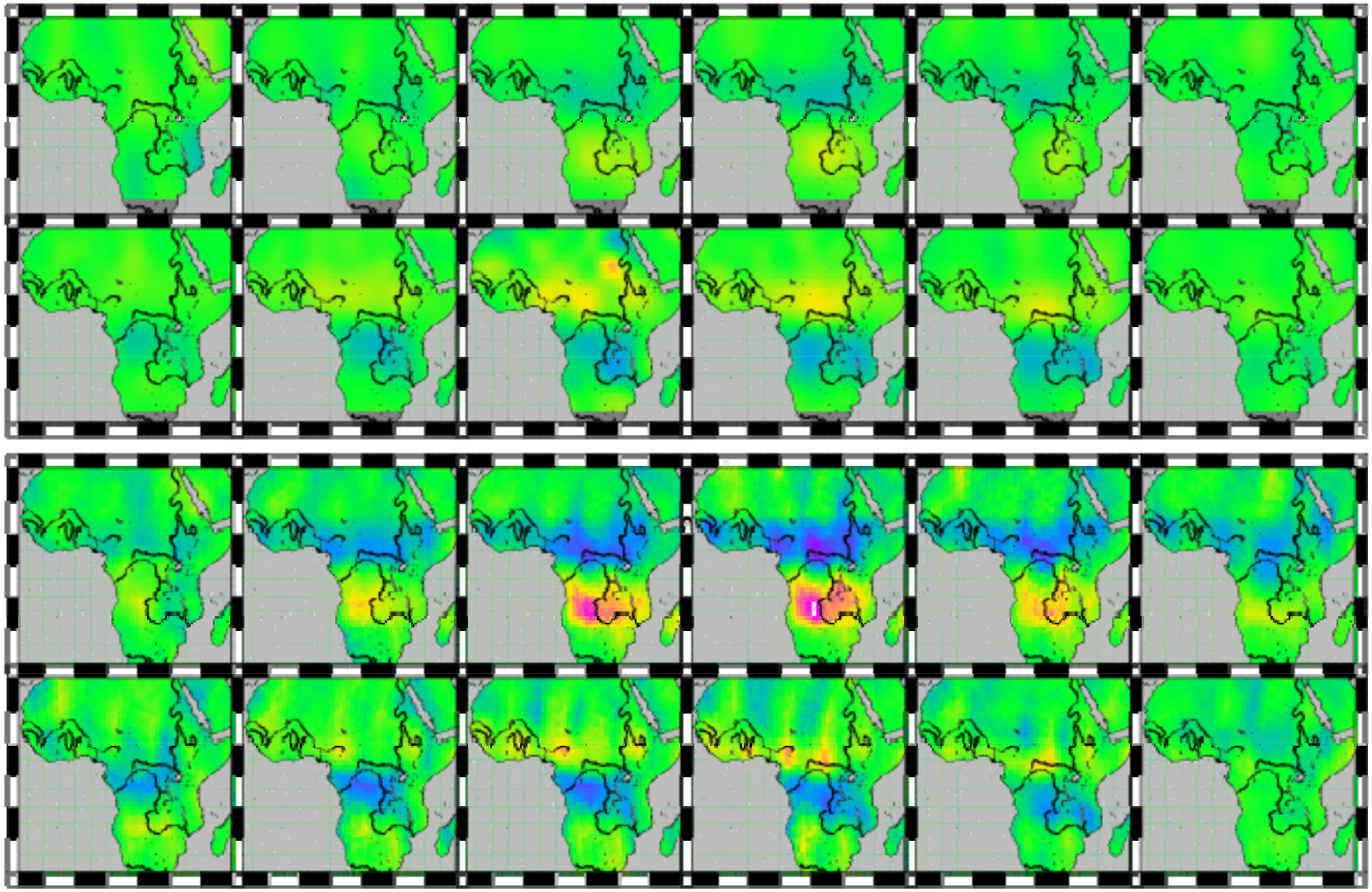
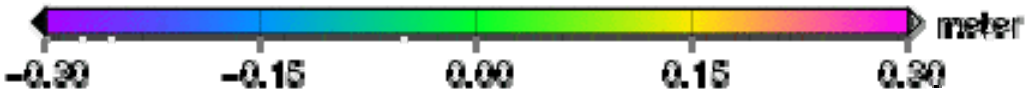
GRACE
Gravity Recovery And Climate Experiment

Africa (04/01-04/12)

Smoothed to 600km

Harmonics





Mascons

Africa (05/01-05/12)

Smoothed to 600km

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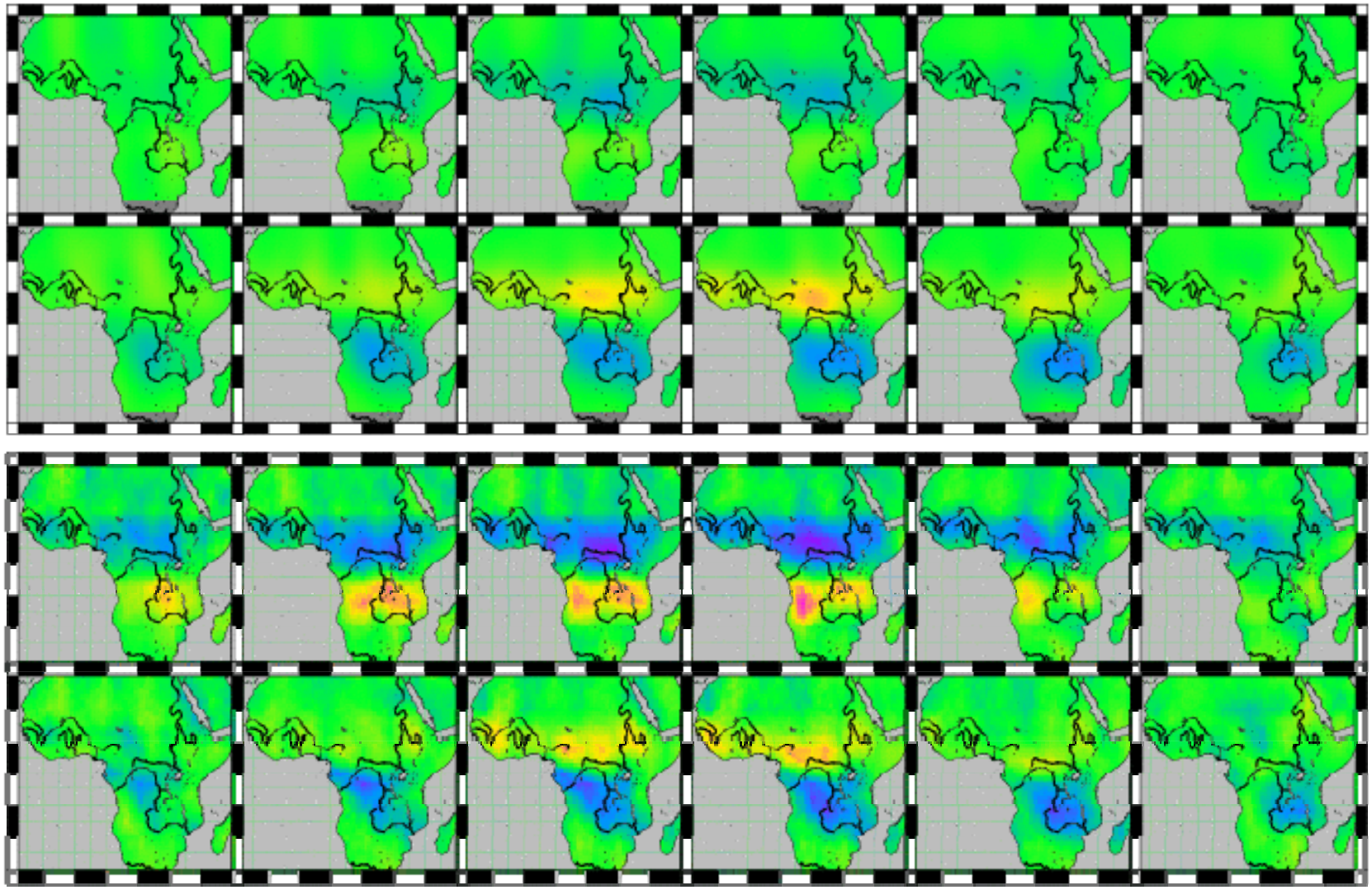

Mascons

Amazon (04/01-04/12)

Smoothed to 600km

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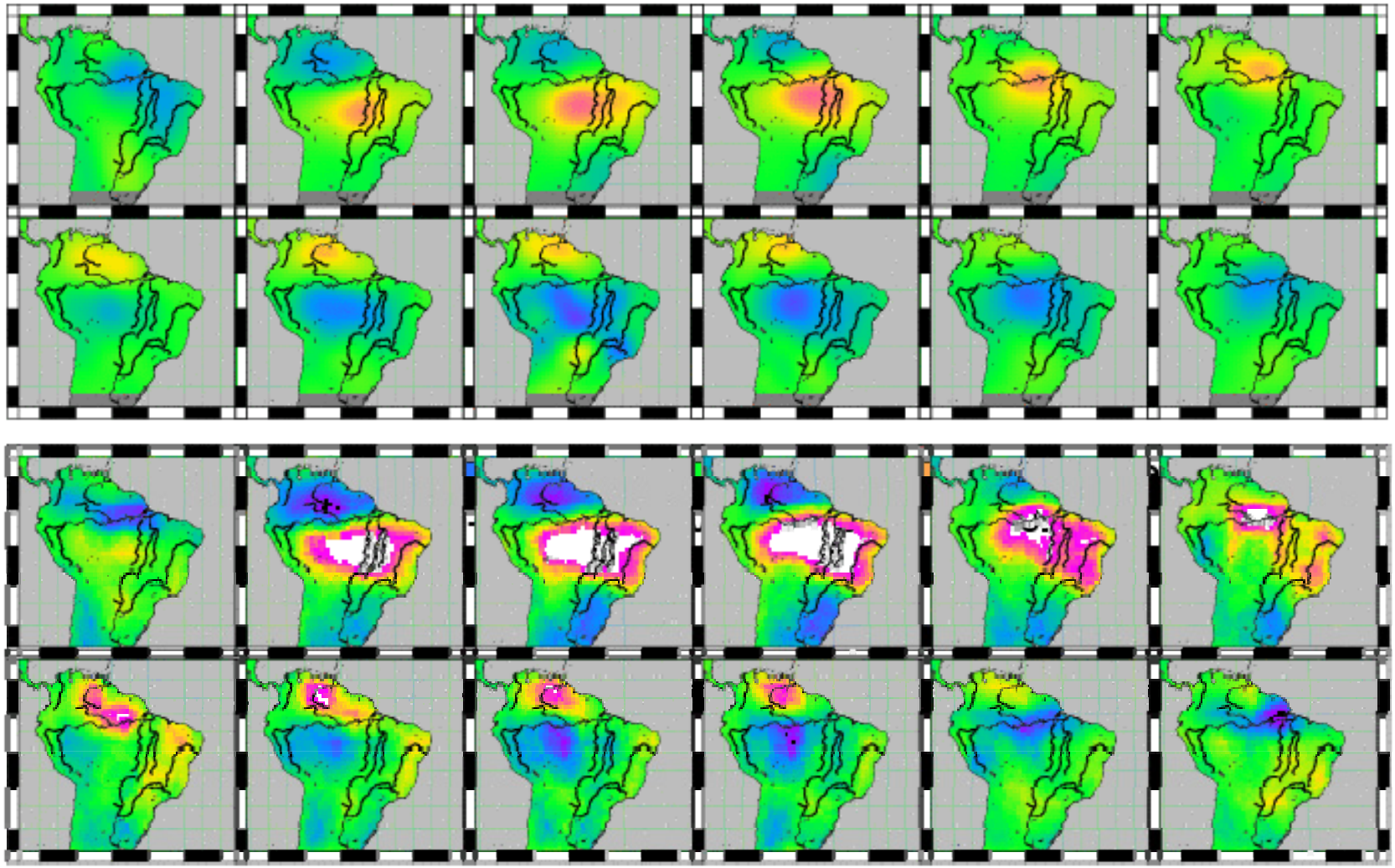

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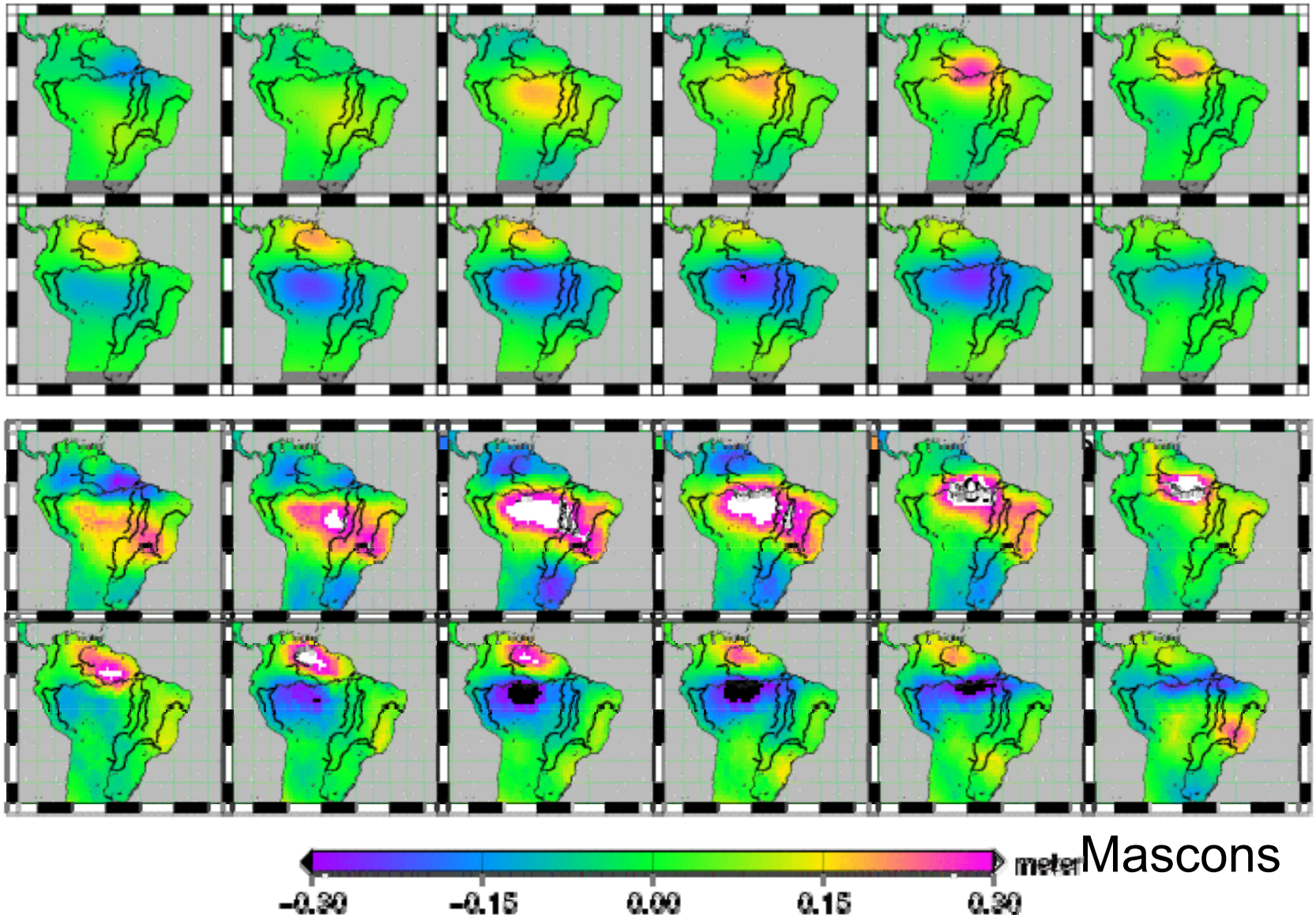

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Australia (04/01-04/12)

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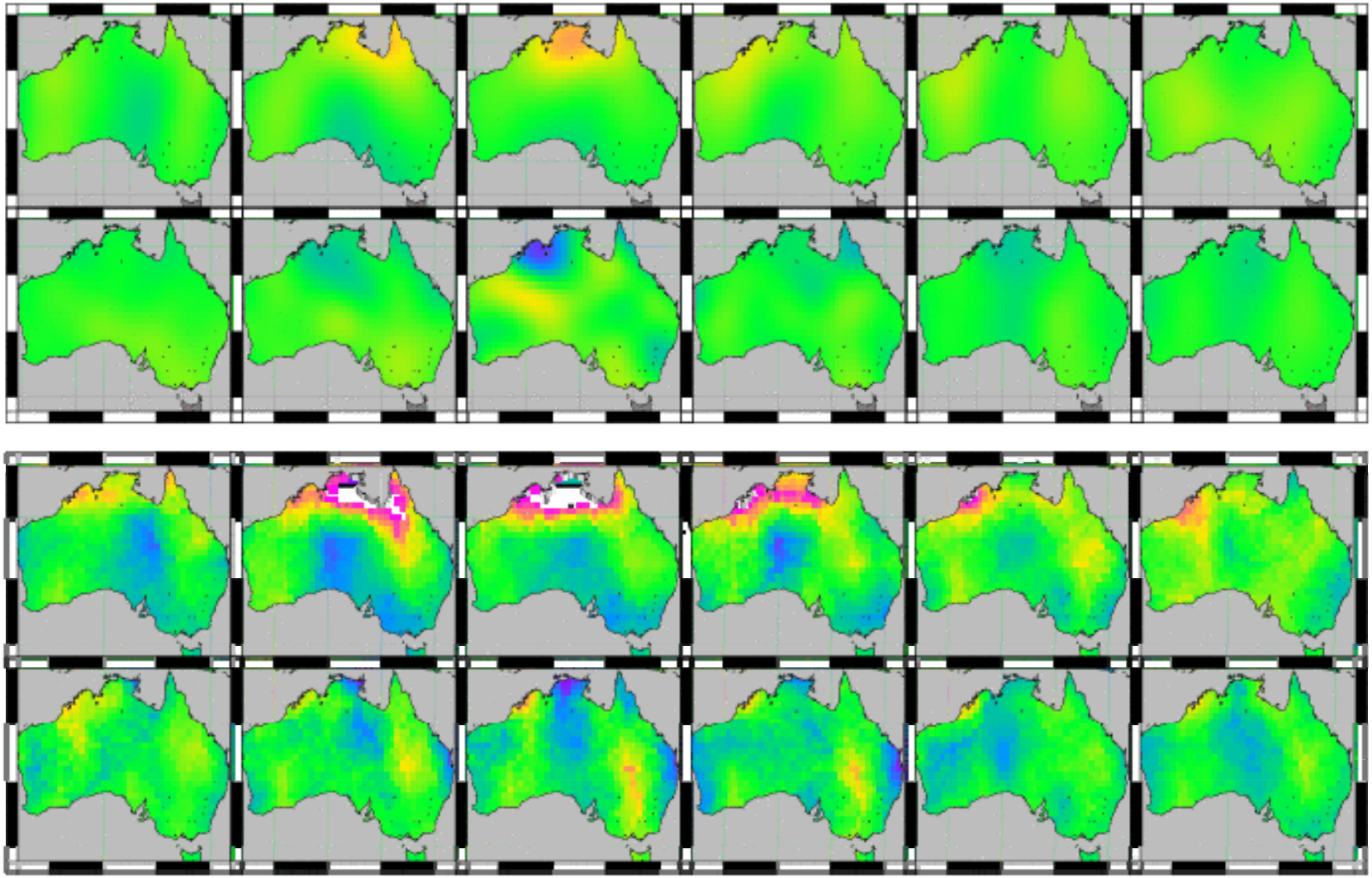

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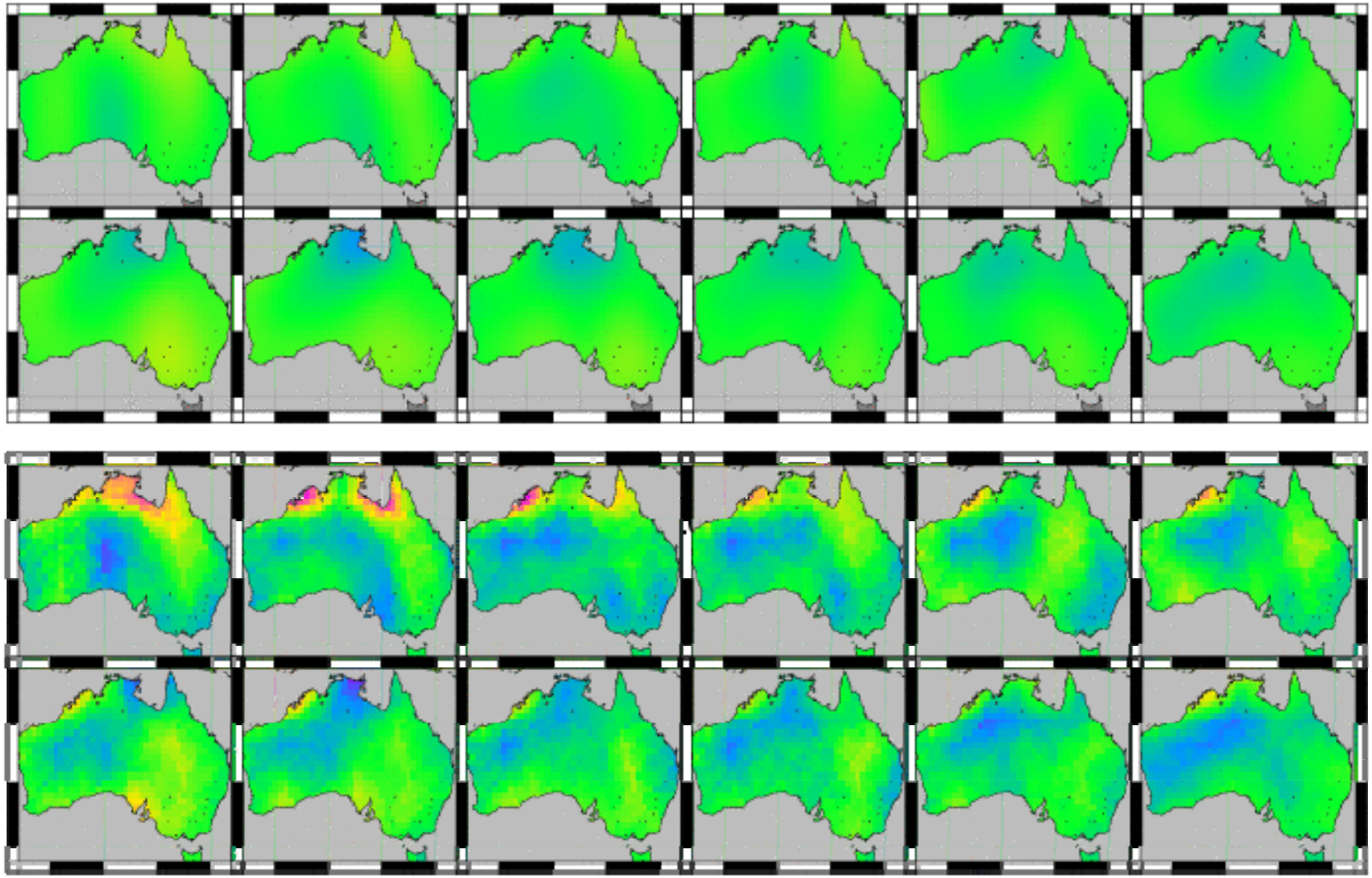
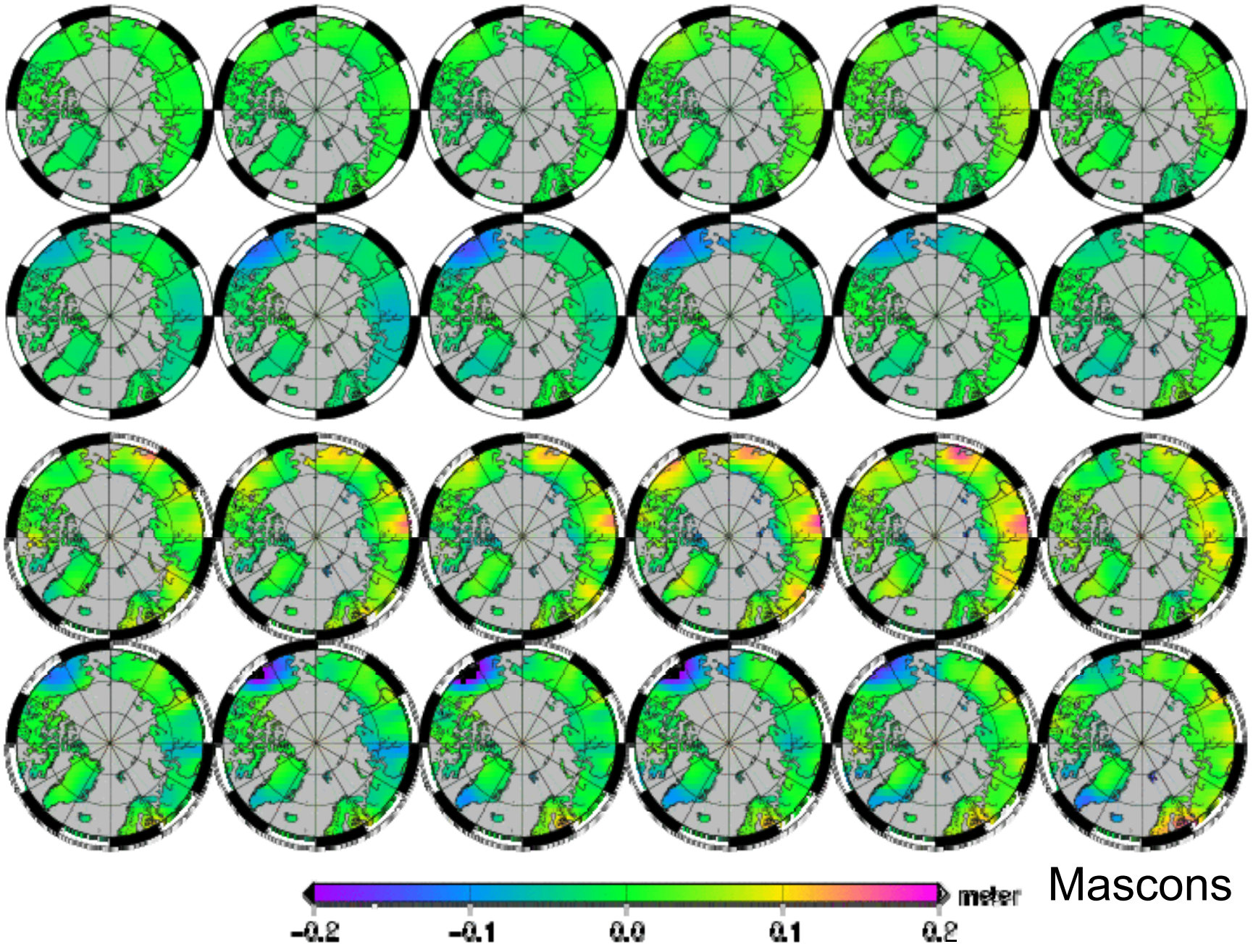


Mascons

Arctic (04/01-04/12)

Smoothed to 600km



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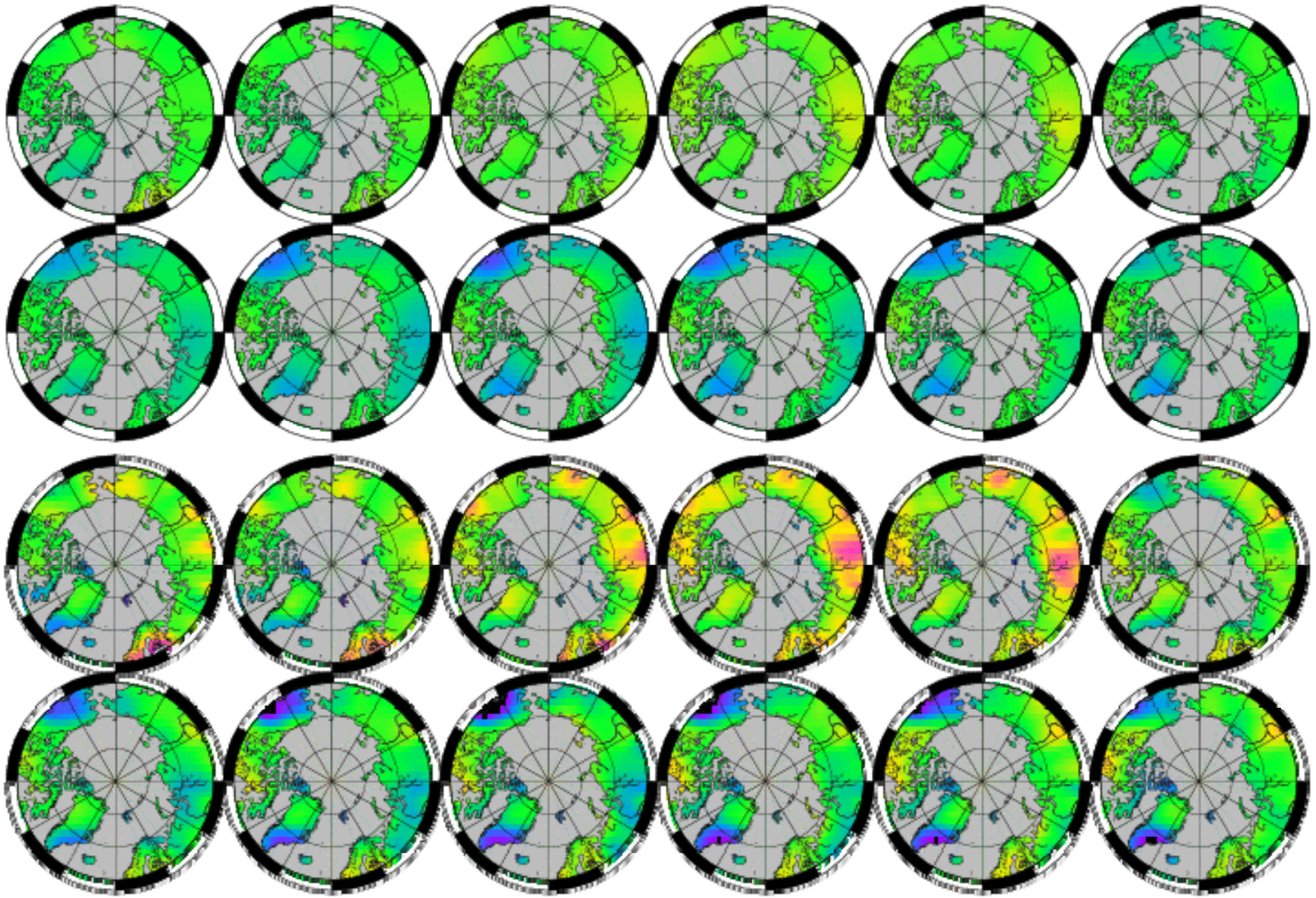
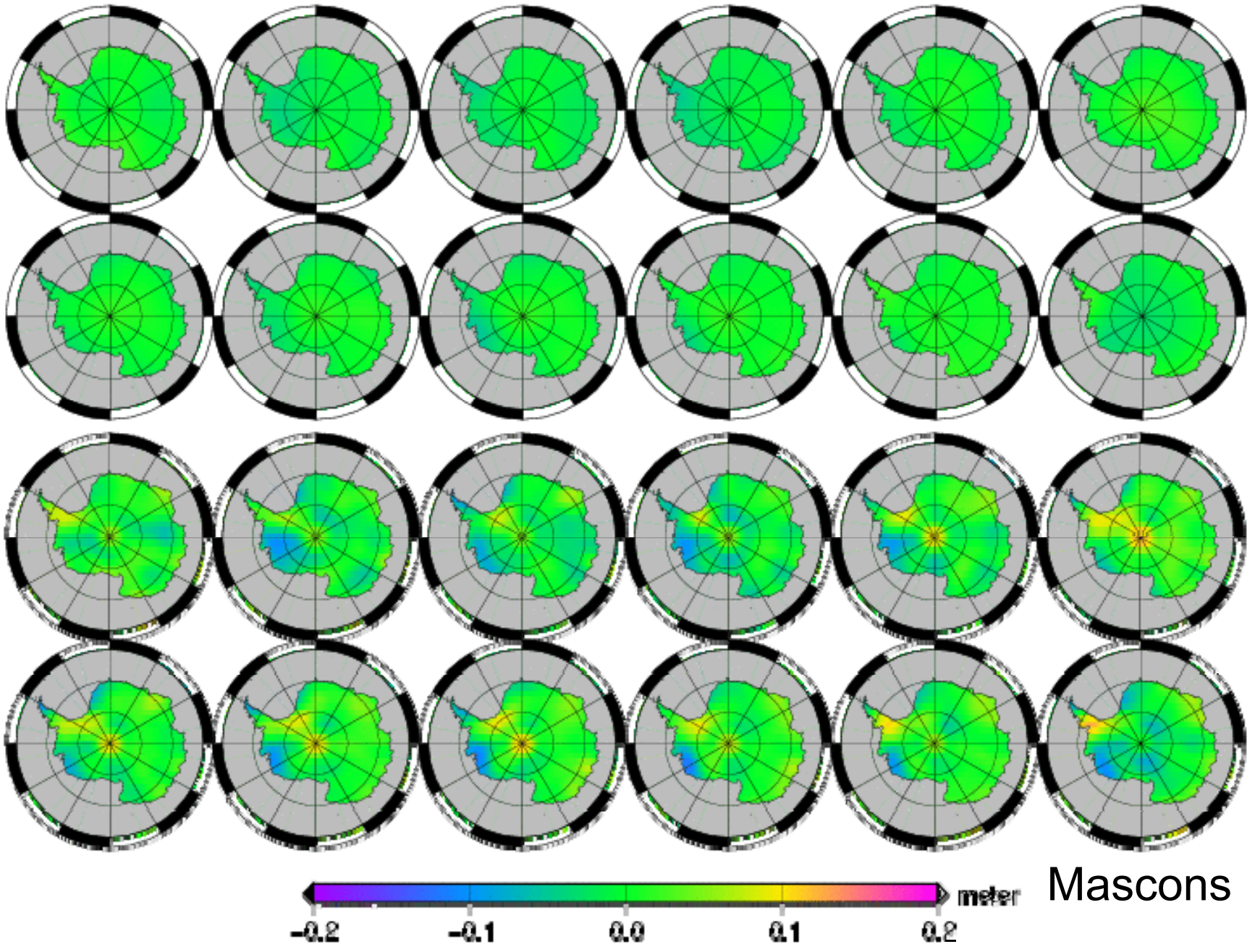


Mascons

Antarctica (04/01-04/12)

Smoothed to 600km



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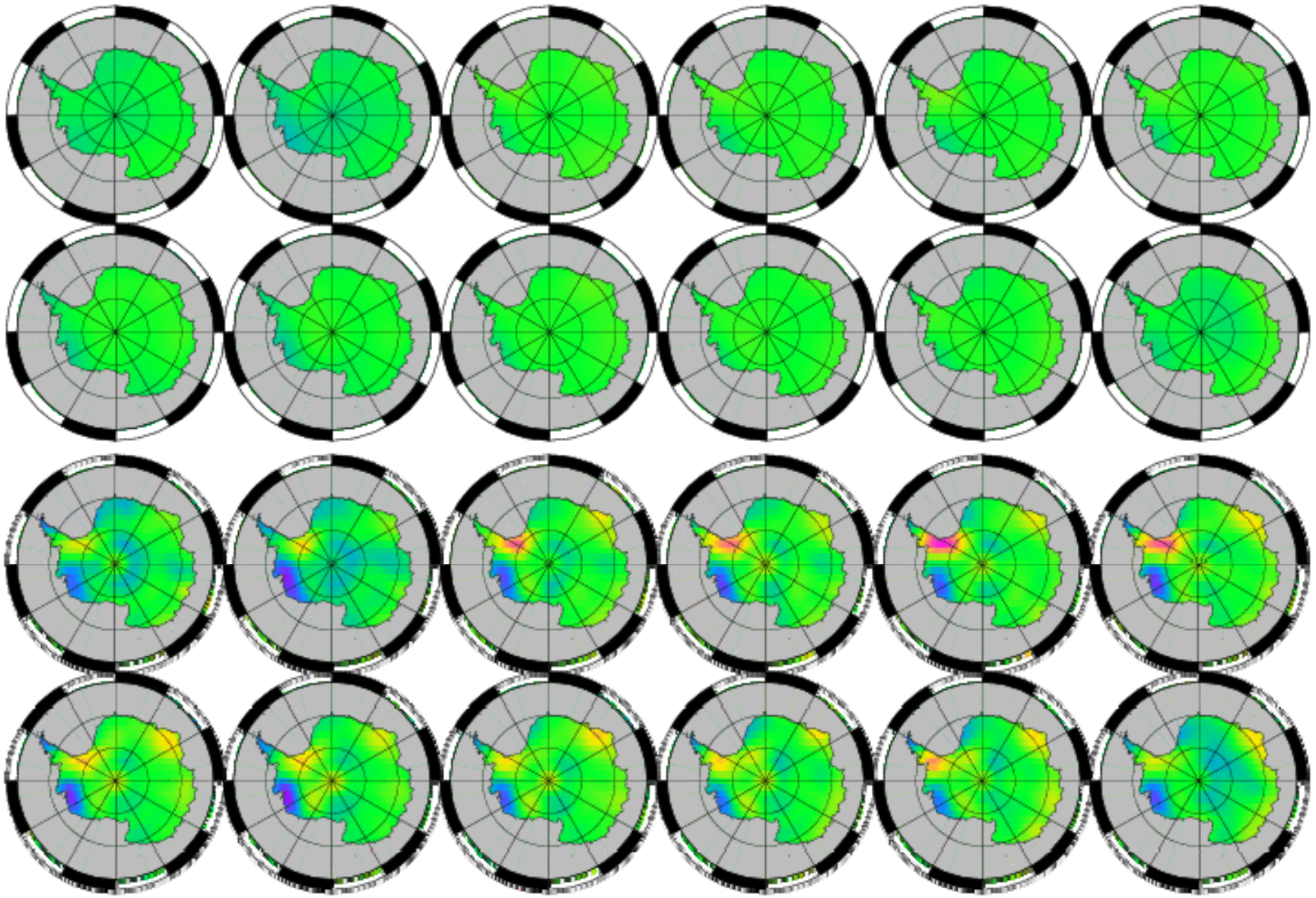
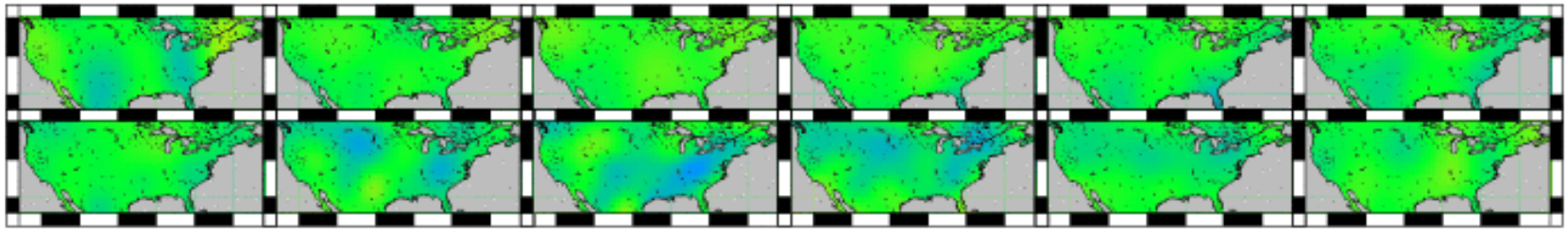


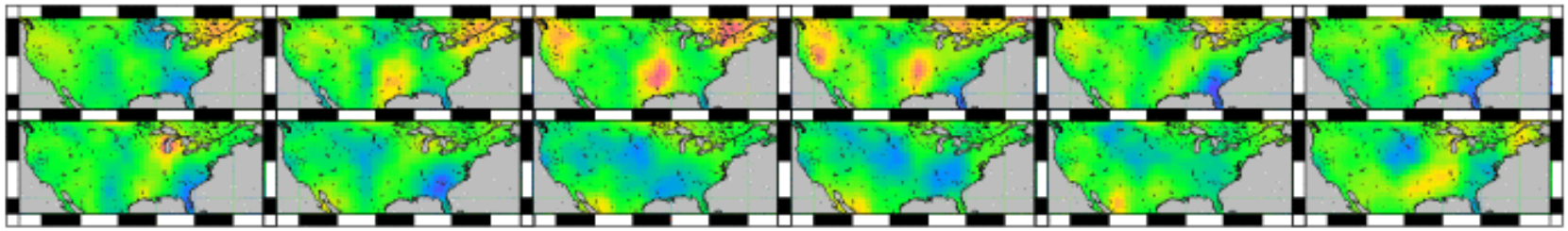
Mascons

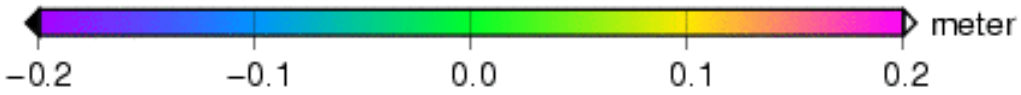
Con. US (04/01-04/12)

Smoothed to 600km

Harmonics







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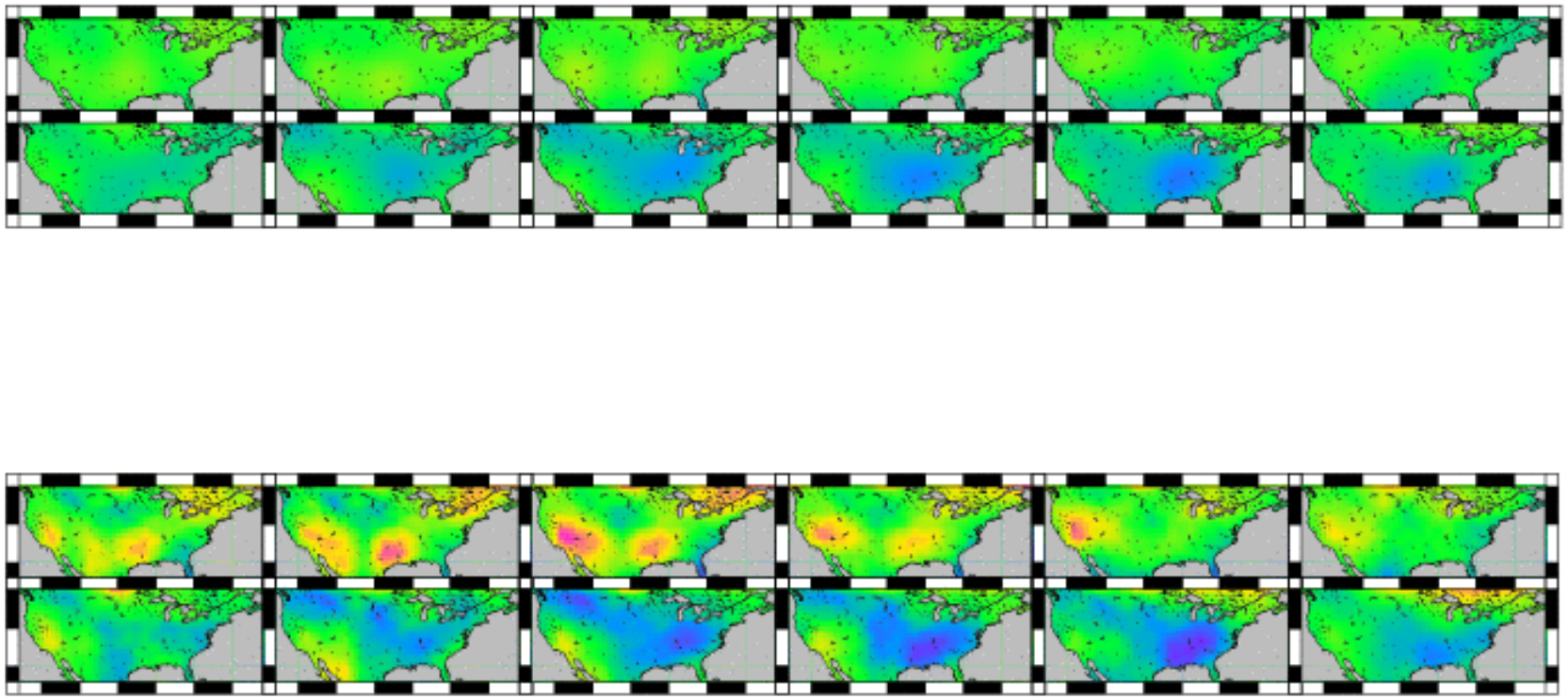

Mascons

South Asia (04/01-04/12)

Smoothed to 600km

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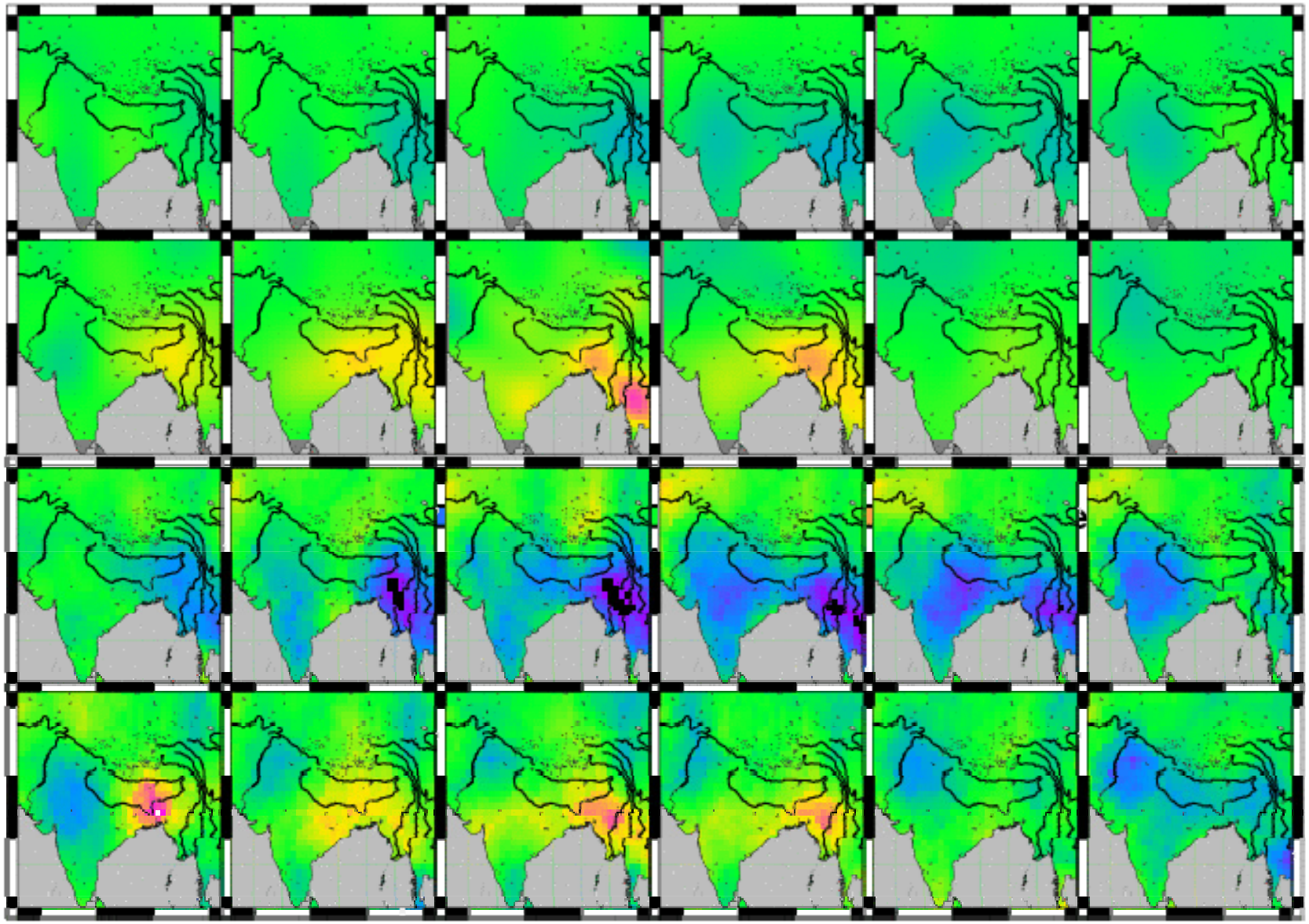

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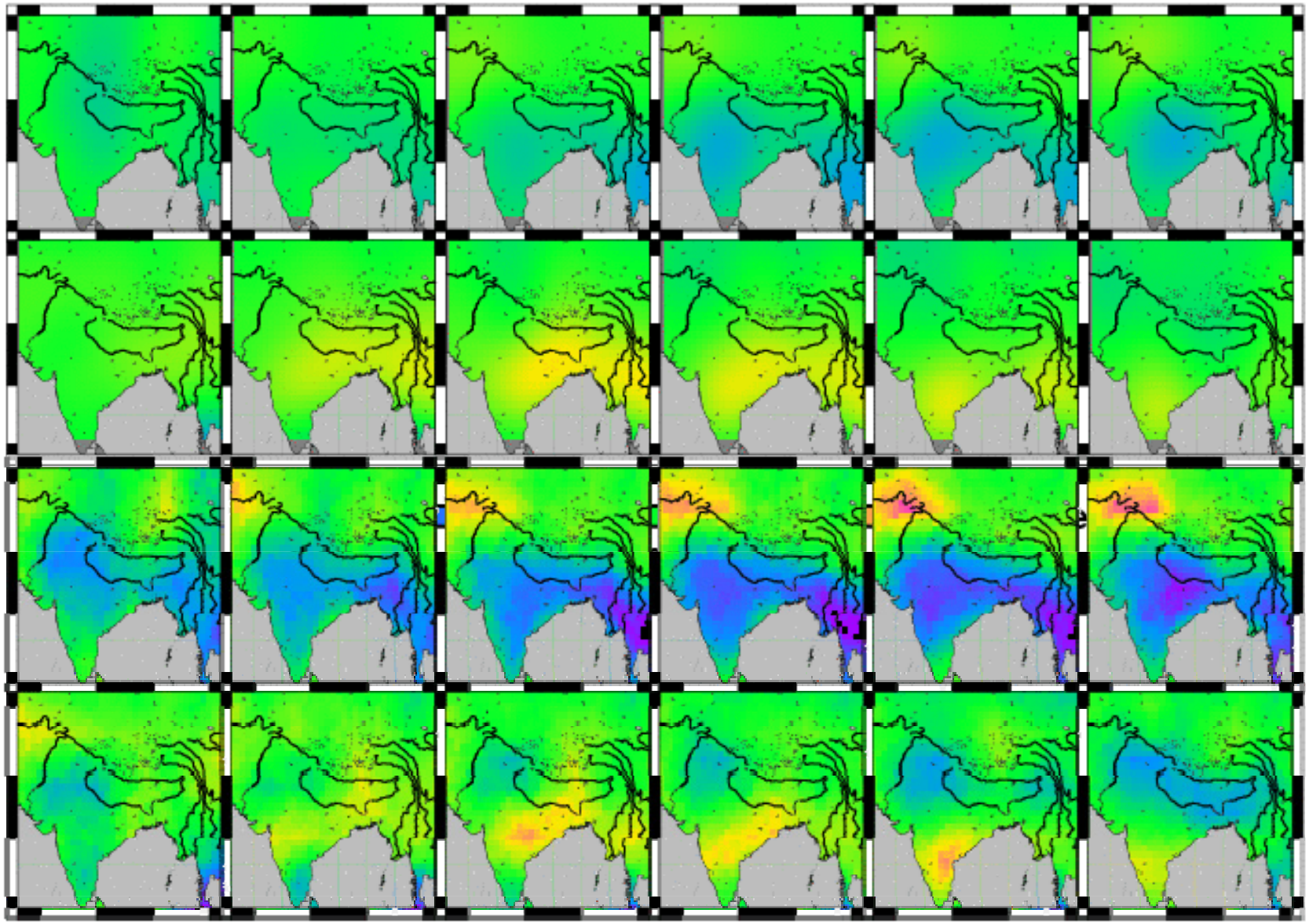

Mascons

Summary-1

- Mascon solutions computed for entire land area of Earth with several variants from Jul. 2003 through Dec. 2005
  - –Automated scripts developed, “pipeline” now in place

- Solutions generally consistent with harmonics for large features but appear able to resolve and localize smaller features more cleanly

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Summary-2

- Greenland solutions generally consistent with areas of max ice mass loss in South, but mascons seem to clearly identify sub-regions of ice mass growth
  - –May be amplified by mascon sensitivity and ground tracks
    - – irregular coverage, errors due to tides in Arctic or other leakage from nearby sources?
    - –Under detailed analysis
- Although mascons are technically 30+ years old, gravity/geodesy community has vastly more experience with harmonics and thus we are still learning the full advantages, limitations, and idiosyncrasies of mascons

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Future Works

- Comparisons with hydrology models & in-situ data will be used for selection of solution strategy in general.
- Mascon solution strategies
    - Submonthly intervals
    - Correlation between regional mascon solutions
    - Sensitivity to the modeling errors

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Background Material

$$\Delta \mathbf{H}^{(\phi,\lambda)}_{\mathbf{water}} = \frac{2\pi \mathbf{a_e}}{3} \frac{\bar{\rho}_{\mathbf{earth}}}{\rho_{\mathbf{water}}} \sum_{\ell=0}^{\infty} \sum_{\mathbf{m}=0}^{\ell} \frac{2\ell+1}{1+\mathbf{K}_\ell} \mathbf{W}_\ell \bar{\rho}_{\ell \mathbf{m}} (\sin\phi) \cdot \left[\Delta \bar{\mathbf{C}}_{\ell \mathbf{m}} \cos \mathbf{m}\lambda + \Delta \bar{\mathbf{S}}_{\ell \mathbf{m}} \sin \mathbf{m}\lambda \right]$$

W_ℓ = Gaussian smoothing factor

K_ℓ = Load Love number

$\bar{\rho}_{\ell m}$ = Normalized Legendre Function

$\bar{\rho}_{earth}$ = Mean density of Earth

ρ_{water} = Density of water

$$\Delta \bar{\mathbf{C}}_{\ell \mathbf{m}} = \bar{\mathbf{C}}_{\ell \mathbf{m}\,\mathbf{monthly}} - \bar{\mathbf{C}}_{\ell \mathbf{m}\,\mathbf{mean}}$$

$$\Delta \bar{\mathbf{S}}_{\ell \mathbf{m}} = \bar{\mathbf{S}}_{\ell \mathbf{m}\,\mathbf{monthly}} - \bar{\mathbf{S}}_{\ell \mathbf{m}\,\mathbf{mean}}$$

(Swenson and Wahr, 2002)

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